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NONINVASIVE MEDICAL DIAGNOSTICS & TREATMENT USING ULTRASONICS

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INTRODUCTION

In parallel to the industrial application of NDE to flaw detection and material property determination, the medical community has successfully adapted such methods to the noninvasive diagnostics and treatment of many conditions and disorders of the human body. As in NDT, medical testing relied heavily on visual and acoustic methods. The introduction of radiography, MRI, electromagnetics and ultrasonics as well as computers and imaging devices have made an enormous impact on the field of medical diagnostics. In spite of various collaborations between individuals from industry and medicine, the two communities were essentially working separately, although using similar tools. A turning point for ASNT occurred during the 1997 Fall ASNT Conference, where two sessions were held on the subject of Medical Diagnostics [1]. The objective was to bring medical doctors and NDT experts together. Such a synergistic pairing led to the sharing of techniques that were already developed and in use by experts in the complementary field. An example of such a success is the use of the CAT (Computed Axial Tomography) scan, which first became a standard medical diagnostic method and then was adapted to the NDE of composite structures. In 1980, Crane and Moran used a medical CAT-scan system to demonstrate the unique capability of the CAT scan to detect flaws, and thus paved the path for this method to become a standard NDE technique. Another example is the MRI (Magnetic Resonance Imaging), which is widely used for medical diagnostics, and it still being explored for practical NDE usage. The authors recognized the potential of joint efforts between the medical and industrial communities, and in August 1995 started exploring cooperative efforts with an emphasis on the destruction of blood clots. The tool common to these investigators had been the use of ultrasonics [2]. Ultrasound offers a wide range of diagnostic and treatment capabilities that result from the broad frequency range, variety of modes and the options of low and high power levels that are available. Medical ultrasonics offers safe, accurate and cost-effective tools for diagnosis and treatment, where no known health hazard is associated with its use at low-power. Noninvasive medical treatment is theoretically superior to invasive surgery, as there should be less tissue injury, pain, blood loss and more rapid healing. For NASA, the availability of such technology is very important. The eventual human habitation of space calls for the development of specialized medical technology that addresses the unique problems of space medicine. The authors are directing their current efforts to the application of high power ultrasonics as a treatment tool for blood clot destruction. This would be appropriate in the treatment of heart attacks and stroke, the most common causes of death in the industrialized world. However, an initiative is also underway to expand the efforts to the treatment of cancer.

MEDICAL DIAGNOSTIC APPLICATIONS

Ultrasonic technology emerged as a medical diagnostic technology in the late 1960's and the field of obstetrics has been one of the first applications [3]. The most widely used techniques today are pulsed echo (2.0 to 7.0 MHz) and Doppler imaging (2 to 4 MHz). Currently used equipment offers real-time imaging, where the moving fetus is viewed on a color monitor. Pulse echo techniques are employed with the transducer coupled either in contact, immersion or using a liquid delay line. To obtain instant images, a transducer array is used and the reflected signals are monitored. The sensitivity and resolution have been improved to a level that allows viewing of even the movements of the fetal heart, and to conduct accurate measurements on the monitor. Such measurements form the cornerstone of the assessment of fetal gestational age, size and health. Progressively, ultrasonics has become an indispensable tool for many medical diagnostic applications. It has a vital role in the assessment of pregnant woman, in patients with heart disease, stroke and disorders of the vascular system, and in imaging of other vital organs such as the liver, kidneys, as well as the abdomen and soft tissues. An example of the capability of pulse-echo imaging can be viewed in Figure 1. This capability allows the examination of atherosclerosis and other disease processes.

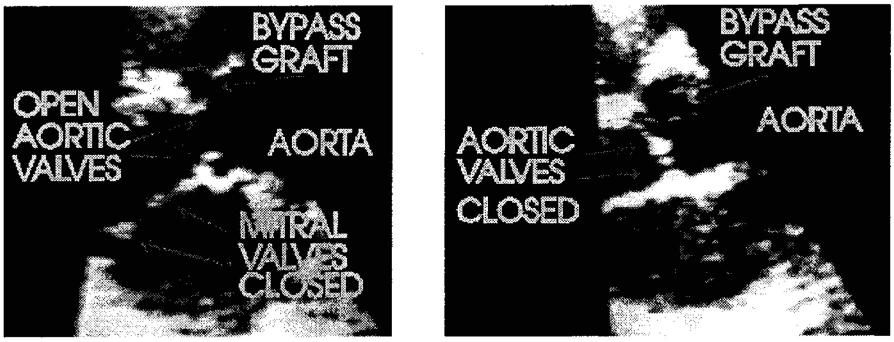

Figure 1: A pulse echo imaging of the Aortic valve in real time, allowing visualization of the heart valve in motion. [Ref-. http://www.webcom.com/ldvonch/cardult.html].

The Doppler shift principle has been used for a long time in fetal heart rate detectors. Recent developments, such as the use of real-time color flow mapping which clearly depicts the flow of blood in the vessels, and allows measurement determinations makes the method a very effective diagnostic tool. The use of real-time color flow mapping clearly depicts the flow of blood in the vessels. Color Doppler is particularly indispensable in the diagnosis and assessment of heart valve disorders, congenital heart abnormalities and the visualization of reduced blood flow in diseased vessels. The development of real-time imaging with the selectable combination of color hues onto shades of gray has added a powerful imaging capability for viewing subtle tissue details. This enhancement provides a better interpretation of the ultrasonic images. The use of 3-D imaging is being developed for volumetric measurements as well as to enhance image interpretation and presentation.

MEDICAL TREATMENT

The application of high power ultrasonics for medical treatment was first introduced as a lithotripsy tool for the dissolution of kidney stones, and became a practical method in the late 1970s [4]. Generally, the treatment of blood clots involves issues other than the breakage of stones, and the authors sought the transcutaneous (through the skin) use of focused high power ultrasound [5]. To monitor the progression of the treatment, radiographic imaging is used and enhanced using radiation-absorbing materials (Figure 2). The principle that makes high power ultrasound an effective tool is the induction of shock-waves as a result of forming cavitation bubbles that implosively collapse [6, 7, 8, and 9]. The cavitations are formed when the pressure associated with the wave (at the rarefaction phase) drops below the vapor pressure of the liquid in which the wave propagates. The implosion, i.e. collapse inward, of cavitation occurs mostly when the wave cycle turns to the compression phase and it induces shock waves. The larger the cavitation bubble, the more violent is its collapse, and the more effective its eroding effect [6]. However, the requirement for large wavelengths is subject to diffraction limits causing difficulties in focusing the wave. The authors have conceived a novel concept that allows modulation of LF and HF forming large and effective cavitation in a constrained focal zone. To aid in their research, the authors used a flash-photography dark-field system to view the cavitation. High power ultrasonic waves induce a variety of effects that can be useful tools, including streaming which is a strong flow of the liquid, particularly at the focal spot (see Figure 3). Generally, ultrasound causes rapid and reversible damage to tissues making it attractive for various medical treatment requirements, including cancer.

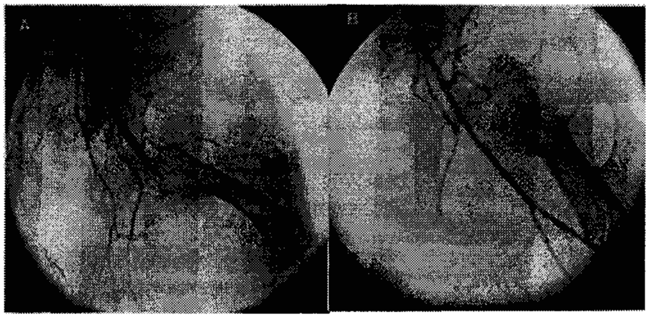

FIGURE 2: Angiographic example of the effect of transcutaneous ultrasound on the left iliofemoral artery of a rabbit, where:
A. Blocked artery.
B. Recovered artery after 30 minutes of treatment.

FIGURE 3: Water streaming at the focus of a 250-KHz lens.

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